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Yamamoto

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(54) **ECONOMICAL SYNCHRONIZATION SYSTEM FOR ASYNCHRONOUS TRANSFER MODE MOBILE COMMUNICATION NETWORK WITHOUT DEPENDENCE ON EXTERNAL SYSTEM**

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(58) **Field of Search** 370/324, 328, 370/331, 335, 336, 338, 350, 395, 503, 508, 252, 519, 329, 395.1, 340; 455/13.2, 502, 503, 524

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,696,052 A	*	9/1987	Breeden	455/503
4,800,560 A	*	1/1989	Aoki et al.	370/324
4,850,032 A	*	7/1989	Freeburg	455/503
5,293,380 A	*	3/1994	Kondo	370/337
5,479,409 A	*	12/1995	Dupuy et al.	370/337
5,519,710 A	*	5/1996	Otsuka	370/337
5,722,080 A	*	2/1998	Kondo	455/502
5,809,426 A		9/1998	Radojevic et al.	455/502
5,828,659 A	*	10/1998	Teder et al.	370/328
5,924,034 A	*	7/1999	Dupuy	455/440
6,009,086 A	*	12/1999	Freeburg et al.	370/331
6,052,371 A	*	4/2000	Lemieux	370/395
6,151,311 A	*	11/2000	Wheatley, III et al.	370/335
6,185,429 B1	*	2/2001	Gehrke et al.	455/502
6,252,890 B1	*	6/2001	Alger-Meunier et al.	370/503

FOREIGN PATENT DOCUMENTS

EP	0578506	1/1994
JP	2-164140	6/1990
JP	6-30466	2/1994

OTHER PUBLICATIONS

Korean Office Action issued Feb. 28, 2001 in a related application with copy of Japanese translation and English translation of the relevant portions of the same.
Japanese Office Action issued Apr. 18, 2000 in a related application and English translation of relevant portions.

* cited by examiner

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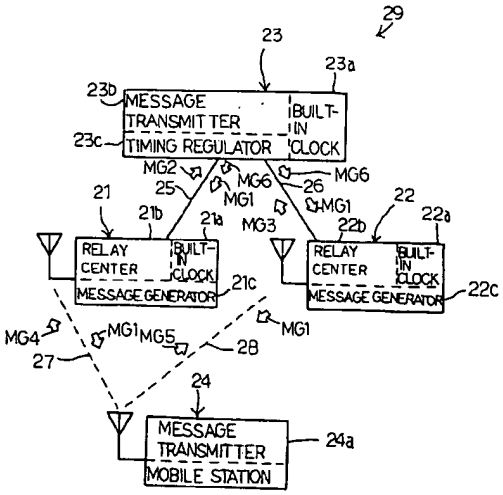
(57) **ABSTRACT**

An asynchronous transfer mode network includes a high-level station and a mobile station in a boundary zone between service cells of wireless base stations connected to the high-level station through asynchronous transfer mode channels, wherein the high level station transmits a control message through the asynchronous transfer mode channels and the wireless base stations to the mobile station and receives response messages from the mobile station through the wireless base stations and the asynchronous transfer mode channels, and determines a difference between transmission time lags along the asynchronous transfer mode channels so as to make built-in clocks provided for the wireless base stations synchronous with one another.

19 Claims, 3 Drawing Sheets



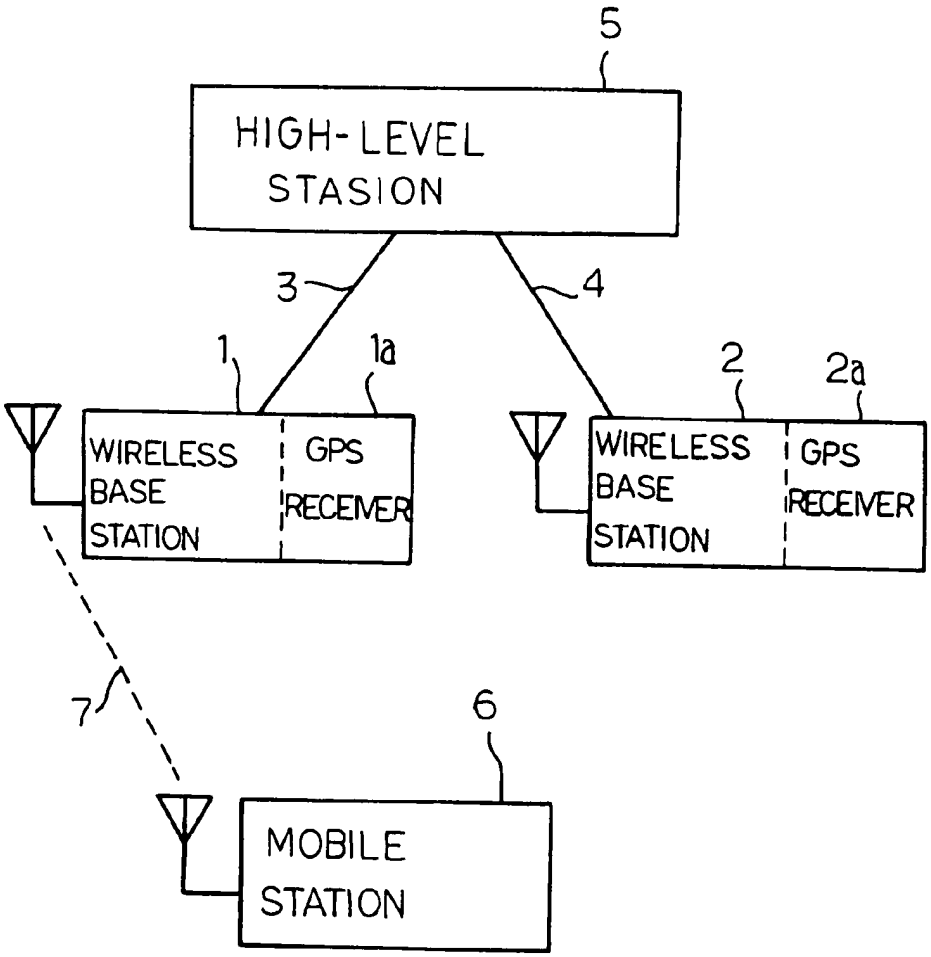


Fig. 1
PRIOR ART

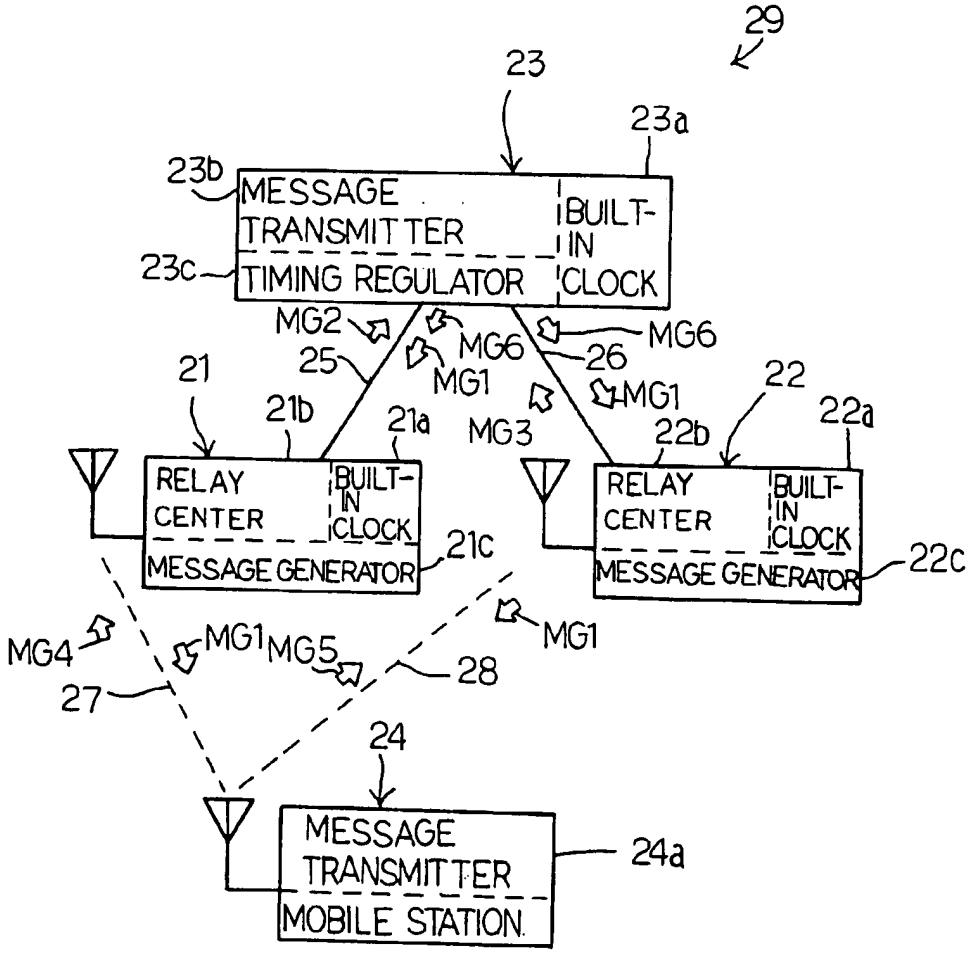

29
23
23a
23b
MESSAGE TRANSMITTER
BUILT-IN CLOCK
23c
TIMING REGULATOR
MG2
MG6
MG6
25
MG1
26
MG1
21
21b
21a
MG3
22
22b
22a
RELAY CENTER
BUILT-IN CLOCK
MESSAGE GENERATOR
21c
RELAY CENTER
BUILT-IN CLOCK
MESSAGE GENERATOR
22c
MG4
MG1
MG5
MG1
28
27
24
MESSAGE TRANSMITTER
MOBILE STATION
24a

Fig. 2

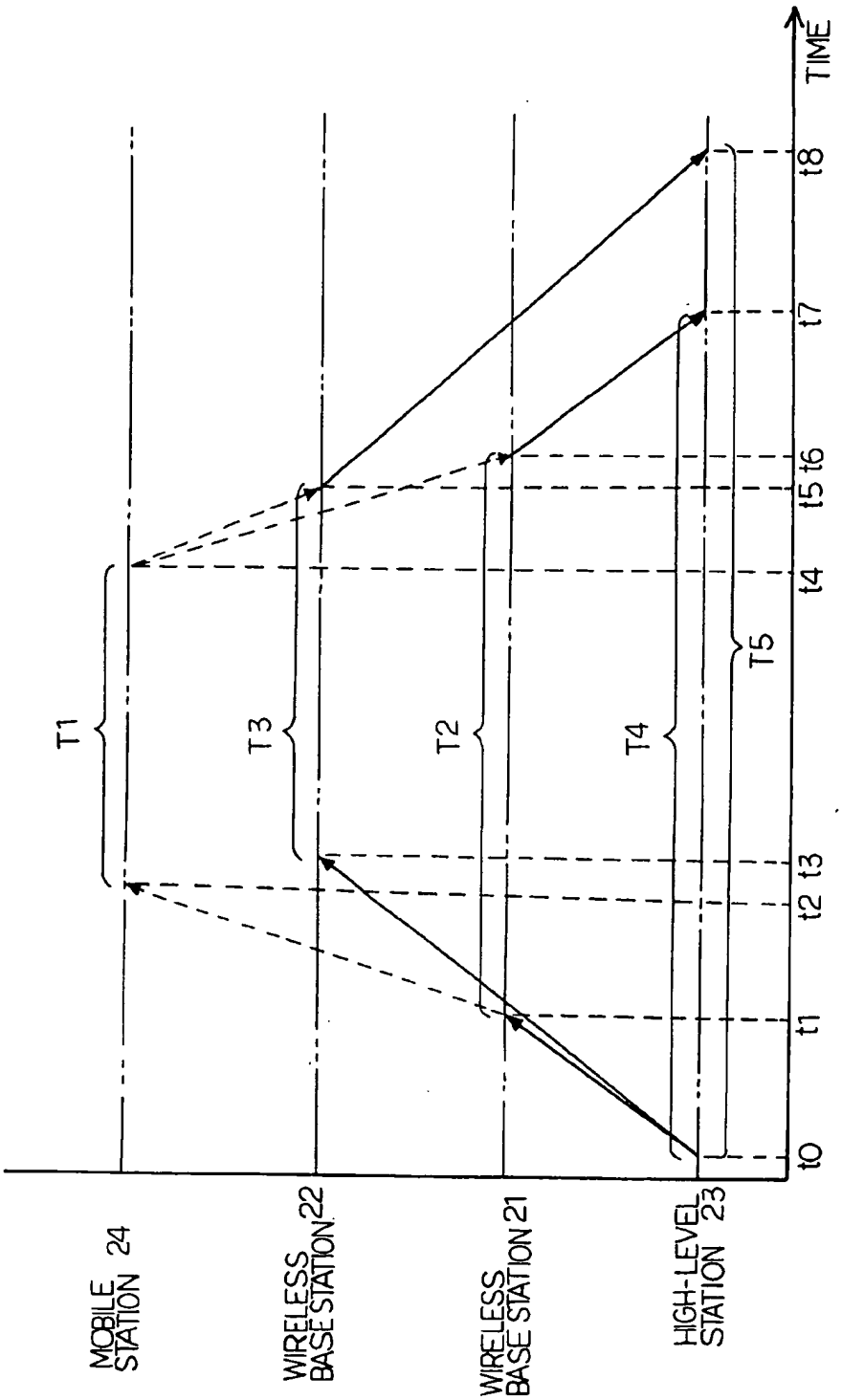

TIME
t0
t1
t2
t3
t4
t5
t6
t7
t8
T1
T2
T3
T4
T5
MOBILE STATION 24
WIRELESS BASE STATION 22
WIRELESS BASE STATION 21
HIGH-LEVEL STATION 23

Fig. 3

ECONOMICAL SYNCHRONIZATION SYSTEM FOR ASYNCHRONOUS TRANSFER MODE MOBILE COMMUNICATION NETWORK WITHOUT DEPENDENCE ON EXTERNAL SYSTEM

FIELD OF THE INVENTION

This invention relates to a mobile communication network and, more particularly, to a synchronization system for base stations incorporated in an asynchronous transfer mode mobile communication network.

DESCRIPTION OF THE RELATED ART

The digital communication channel is broken down into a synchronous transfer mode and an asynchronous transfer mode. The synchronous transfer mode and the asynchronous transfer mode are abbreviated as "STM" and "ATM", respectively. In the synchronous transfer mode, time slots are periodically assigned to digital signals on different channels through the time division multiplexing, and the digital signals are transferred from a base station to a high-level station. Even if there is not any digital signal on a channel, the time slot is still periodically assigned to the channel, and the utilization factor is rather low. Therefore, the synchronous transfer mode is less appropriate for variable traffic data such as voice data and packet data. On the other hand, digital signals on different channels are formed into fixed-length cells, and the fixed-length cells are multiplexed depending upon the traffic on each channel. For this reason, the asynchronous transfer mode is more appropriate for the variable traffic data.

A mobile communication network is expected to transmit variable traffic data, and the asynchronous transfer mode is desirable for the mobile communication network. A high-level station is shared between plural base stations in the mobile communication network, and a synchronization between the base stations is required for a hand-off.

Signal transmission timings at the base stations are controlled in a time division multiple access, which is abbreviated as "TDMA", system. The time division multiple access establishes a synchronization between the base stations with respect to the high-level station in the mobile communication network, and is effective against the silent time due to the hand-off.

A code division multiple access, which is abbreviated as "CDMA", system is attractive to the communication service, because the user channels per unit band width are more than the user channels of the time division multiple access. The code division multiple access requires the synchronization for continuous communication at the hand-off.

Nevertheless, it is not easy to establish the synchronization between the base stations with respect to the high-level station in the asynchronous transfer mode network, because the transmission delay is always varied.

Japanese Patent Publication of Unexamined Application No. 6-30466 proposes an asynchronous transfer mode mobile communication system between plural base stations and a control station. The asynchronous transfer mode mobile communication system includes a mobile communication controlling station and wireless base stations communicable with the mobile communication controlling station through plural transmission channels. The transmission channels are respectively connected to signal processing units incorporated in the mobile communication controlling station. A channel controller is provided between modulator/demodulator units and the transmission channels. When a hand-off is required, the wireless base station needs to change a modulator/demodulator unit communicating with a mobile station to another modulator/demodulator unit, and the channel controller connects the new modulator/demodulator to the transmission channel already used. Thus, the channel controller changes the connection between the modulator/demodulator units and the transmission channels at the hand-off, and any interruption does not take place in the communication with the mobile station. However, the Japanese Patent Publication of Unexamined Application is silent to the synchronization between the base stations.

If a high-precision clock signal is shared between wireless base stations, the high-precision clock signal makes the base stations synchronous with one another with respect to the high-level station. FIG. **1** illustrates the prior art asynchronous transfer mode mobile communication system proposed as TIA/EIA/IS-95-A system. Wireless base stations **1/2** are connected through asynchronous transfer mode channels **3/4** to a high-level station **5**, and a mobile station **6** is communicating with the wireless base station **1** through a radio channel **7**. The global positioning system is available for the synchronization between the wireless base stations **1** and **2**. The global positioning system is abbreviated as "GPS", and the twenty-four space satellites broadcast high-precision clock signal indicative of the current time. GPS receivers ***1a/2a*** are incorporated in the wireless base stations **1/2**, respectively, and the high-precision clock signal establishes the synchronization between the wireless base stations **1/2**.

A cesium atomic clock can provide a highly reliable clock signal, and is available for the synchronization between the base stations in the asynchronous transfer mode mobile communication system.

However, the cesium atomic clock is so expensive that the installation in each base station is not feasible. On the other hand, the GPS receiver ***1a/2a*** is economical, and the prior art synchronization system shown in FIG. **1** is feasible in view of the cost. However, the space satellites can not eternally broadcast the high-precision clock signal. For this reason, the prior art synchronization system is less reliable.

SUMMARY OF THE INVENTION

It is therefore an important object of the present invention to provide a synchronization system for an asynchronous transfer mode mobile communication network which is economical and reliable.

To accomplish the object, the present invention proposes to periodically measure a difference in transmission time lags along asynchronous transfer mode channels.

In accordance with one aspect of the present invention, there is provided a n asynchronous transfer mode network comprising a plurality of low-level stations communicable with at least one mobile station in a boundary zone between service cells of the plurality of low-level stations, a high-level station communicable with the plurality of low-level stations through respective asynchronous transfer mode channels, and a synchronization system including a plurality of clocks respectively associated with the high-level station and the low-level stations and independently indicating current times, a message transmitting unit associated with the high-level station and concurrently transmitting a control message from the high-level station to the plurality of low-level stations through the asynchronous transfer mode channels, a plurality of message relaying units respectively associated with the plurality of low-level stations, replaying

the control message from one of the plurality of low-level stations to the at least one mobile station, respectively receiving a plurality of first response messages respectively supplied from the at least one mobile station to the plurality of low-level stations and respectively transmitting a plurality of second response messages from the plurality of low-level stations through the asynchronous transfer mode channels to the high-level station, at least one first message generator associated with the at least one mobile station and transmitting the plurality of first response messages to the plurality of message relaying units after the at least one mobile station receives the control message, a plurality of second message generators respectively connected to the plurality of message relaying units and respectively producing the plurality of second response messages each representative of the current time indicated by the clock associated with one of the plurality of low-level stations and a first message transmission routine from aforesaid one of the plurality of low-level stations to the at least one mobile station and vice versa and a timing regulator connected to the message transmitting unit and determining a difference between transmitting time lags along the asynchronous transfer mode channels on the basis of the second response messages and a plurality of second message transmission routines from the high-level station to the at least one mobile station and vice versa for supplying a piece of control information representative of the difference between the transmitting time lags to the plurality of low-level stations.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the synchronization system will be more clearly understood from the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a schematic view showing the prior art synchronization system for an asynchronous transfer mode mobile communication system;

FIG. 2 is a schematic view showing a synchronization system for an asynchronous transfer mode mobile communication network according to the present invention; and

FIG. 3 is a timing chart showing a determination of transmission time lags carried out by the synchronization system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 2 of the drawings, an asynchronous transfer mode mobile communication network comprises plural wireless base stations **21/22**, a high-level station **23** such as a mobile communication control station and plural mobile stations **24**. Although the mobile stations **24** are communicating with the wireless base stations **21/22**, only one mobile station **24** is shown in FIG. **2**. The wireless base stations **21/22** are connected through asynchronous transfer mode channels **25/26** to the high-level station **23**, and the mobile station **24** transmits a transmitting signal **27** to a radio channel **27/28**. The high-level station **23** and the wireless base stations **21/22** are stationary, and service areas or service cells are assigned to the wireless base stations **21/22**, respectively. The mobile stations **24** are movable in the service cells, and some mobile stations **24** are moved from certain service cells to different service cells adjacent to the certain service cells.

In this instance, a 155 Mbps asynchronous transfer mode network provides the asynchronous transfer mode channels **25/26**, and a TDMA mobile telephone network provides the radio channels **27/28**. For this reason, the mobile station **24** communicates through the radio channels **27/28**, the wireless base stations **21/22**, the asynchronous transfer mode channels **25/26** and the high-level station **23** to another mobile station or a telephone. For this reasons the wireless base stations **21/22** for the communications between the mobile stations **24** or the mobile station **24** and the telephone serve as low-level stations, respectively.

Built-in clocks **21*a*/22*a*/23*a*** are incorporated in the wireless base stations **21/22** and the high-level station **23**, respectively, and the built-in clocks **21*a*/22*a*/23*a*** independently indicate time. The price of the built-in clock **21*a*/22*a*/23*a*** is much smaller than that of the cesium atomic clock. For this reason, the built-in clocks **21*a*/22*a*/23*a*** are employable in the asynchronous transfer mode mobile communication network according to the present invention.

The high-level station further includes a message transmitter **23*b*** and a timing regulator **23*c***. The message transmitter **23*b*** generates a control message MG1 representative of an initiation of timing regulation, and concurrently transmits the control message MG1 to the timing regulator **23*c*** and the wireless base stations **21/22**. In this instance, a layer-3 message in the TDMA mobile telephone system is expanded so as to define the control message MG1. The control message MG1 is transmitted through the asynchronous transfer mode channels **25/26** to the wireless base stations **21/22**.

The timing regulator **23*c*** is responsive to the control message MG1, and starts to establish a synchronization in the asynchronous transfer mode network. The timing regulator **23*c*** measures the lapses of time from the receipt of the control message MG1 to receipt of each response message MG2/MG3 from the wireless base station **21/22**. The response message MG2 represents a lapse of time from the receipt of the control message MG1 to receipt of a response message MG4 from the mobile station and the current time indicated by the built-in clock **21*a***. Similarly, the response message MG3 represents a lapse of time from the receipt of the control message MG1 to receipt of a response message MG5 from the mobile station and the current time indicated by the built-in clock **22*a***. The timing regulator **23*c*** calculates the difference between the transmission time lags from the high-level station **23** to the wireless base stations **21/22** along the asynchronous transfer mode channels **25** and **26** and the difference between the transmission time lags from the wireless base stations **21/22** to the high-level station **23** on the basis of the lapses of time. When the differences of transmission time lags are determined, the timing regulator **23*c*** checks the response messages MG2/MG3 to see whether or not the transmission time lags are correctly reflected on the built-in clocks **21*a*/22*a***. If not, the timing regulator **23*c*** supplies a control message MG6 to the built-in clocks **21*a*/22*a***. The control message MG6 is representative of putting back the built-in clock **21*a*/22*a*** a certain time or putting the built-in clock **21*a*/22*a*** forward a certain time. Thus, the timing regulator **23*c*** makes the wireless base stations **21/22** synchronous with one another.

The wireless base stations **21/22** are similar in internal arrangement to one another. The wireless base station **21/22** further includes a relay center **21*b*/22*b*** and a message generator **21*c*/22*c***. Although all the relay centers **21*b*/22*b*** can relay the control message MG1 to the mobile station **24**, one of the relay centers **21*b*/22*b*** relays the control message MG1 to the mobile station **24**, and the other relay center does not relay the message MG1 to the mobile station **24**. All the relay centers **21*b*/22*b*** respectively relay the control message MG1 to the associated message generators **21*c*/22*c***, and

report arrivals of the response messages MG4/MG5 to the associated message generators 21c/22c. The message generators 21c/22c start to measure lapses of time from the receipt of the control message MG1 to receipts of the response messages MG4/MG5, respectively. The message generators 21c/22c determine the lapses of time and the arrival times of the response messages MG4/MG5. The message generators 21c/22c respectively generates the response messages MG2/MG3 representative of the lapses of time and the current times or the arrival times, and transmit the response messages MG2/MG3 to the timing regulator 23c.

The mobile station 24 is assumed to be at the boundary between the service cell of the wireless base station 21 and the service cell of the wireless base station 22. The mobile station includes a message transmitter 24a. The message transmitter 24a is responsive to the control message MG1 from either wireless base station 21/22, and introduces a predetermined delay time between the receipt of the control message MG1 and the transmission of the response messages MG4/MG5. The response message MG4 is identical with the response message MG5. In other words, the wireless base station 22 monitors the response message MG4 transmitted to the wireless base station 21, and recognizes the monitored message MG4 as the response message MG5. The transmission times through the radio channels 27/28 are exactly measured on the basis of the phase difference, and the arrival times are corrected as if the mobile station 24 is equally spaced from the wireless base stations 21 and 22. In other words, time lag (t6−t5) is equal to zero (see FIG. 3).

The built-in clocks 21a/22a/23a, the message transmitter 23b, the timing regulator 23c, the relay centers 21b/22b, the message generators 21c/22c and the message transmitter 24a as a whole constitute a synchronization system 29 according to the present invention.

The synchronization system 29 determines the transmission time lag as follows. FIG. 3 illustrates message transmission timings and message receiving timings. The high-level station 23 transmits the control message MG1 at time t0, and the wire less stations 21 and 22 receive the control message MG1 at t1 and t3, respectively. The wireless base station 21 relays the control message MG1 to the mobile station 24, and the control message MG1 arrives at the mobile station 24 at t2.

The mobile station 24 introduces the predetermined time delay T1, and transmits the response messages MG4/MG5 to the wireless base stations 21/22 at time t4. The response messages MG4/MG5 arrive at the wireless base stations 21/22 at t5 and t6, respectively. However, the transmission time lag due to the difference in distance between the mobile station 24 and the wireless base stations 21/22 is corrected as if the difference between t5 and t6 is zero. The wireless base stations 21/22 determines the lapses of time T2/T3 and the times when the response messages MG4/MG5 actually arrive at the wireless base stations 21/22. The difference between the lapses of time T2 and T3 is representative of the difference in transmission time lag from the high-level station 23 to the wireless base stations 21/22 along the asynchronous transfer mode channels 25 and 26.

The wireless base stations 21/22 produce the response messages MG2/MG3, and transmit the response messages MG2/MG3 to the high-level station 23. The high-level station 23 determines the lapses of time T4/T5. The difference between the lapses of time T4/T5 contains not only the difference between the transmission time lags from the high-level station 23 to the wireless base stations 21/22 but also the difference between the transmission time lags from the wireless base stations 21/22 to the high-level station 23. For this reason, the difference between the transmission time lags from the wireless base stations 21/22 to the high-level station 23 is expressed as (T5−T4)−(T2−T3). The synchronization system 29 may periodically repeat the timing regulation described hereinbefore.

As will be appreciated from the foregoing description, the synchronization system 29 determines the differences in transmission time lag between the asynchronous transfer mode channels 25 and 26, and supplies the control message MG6 to the wireless base stations 21/22 so as to put the built-in clocks 21a/22a back or forward. As a result, the differences in the transmission time lag are taken into account, and the built-in clocks 21a/22a respectively indicate corrected times available for the synchronization between the wireless base stations 21/22. The synchronization system 29 is never dependent on any external system, and is surely reliable.

Although a particular embodiment of the present invention has been shown and described, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the present invention.

For example, the timing regulator 23c and the message generators 21c/22c may simply determine arrival times and/or transmission times so that the timing regulator 23c calculates the differences in transmission time lag along the arrival times and/or the transmission times.

The wireless base stations 21/22 may communicate with the mobile station through the CDMA channels or another kind of channels.

What is claimed is:

1. An asynchronous transfer mode network comprising:

a plurality of low-level stations communicable with at least one mobile station in a boundary zone between service cells of said plurality of low-level stations;

a high-level station communicable with said plurality of low-level stations through respective asynchronous transfer mode channels; and

a synchronization system including

a plurality of clocks each respectively associated with a corresponding one of said high-level station and said low-level stations, and each clock independently indicating a current time,

a message transmitting unit associated with said high-level station and concurrently transmitting a control message from said high-level station to said plurality of low-level stations through said asynchronous transfer mode channels,

a plurality of message relaying units each respectively associated with a corresponding one of said plurality of low-level stations, for replaying said control message from one of said plurality of low-level stations of said at least one mobile station, each message relaying unit respectively receiving a first response message respectively supplied from said at least one mobile station to said plurality of low-level stations and respectively transmitting a second response message from said plurality of low-level stations through said asynchronous transfer mode channels to said high-level station,

for each mobile station of said at least one mobile station, a first message generator associated with the corresponding mobile station and respectively transmitting said first response messages to said plurality

of message relaying units after said at least one mobile station receives said control message,

a plurality of second message generators each respectively connected to a corresponding one of said plurality of message relaying units and respectively producing said second response message, each second response message representative of the current time indicated by the clock associated with the corresponding one of said plurality of low-level stations and a first message exchange period between said corresponding one of said plurality of low-level stations and said at least one mobile station, and

a timing regulator connected to said message transmitting unit and determining a difference between transmitting time lags along said asynchronous transfer mode channels on the basis of said second response messages and a plurality of second message exchange periods between said high-level station and said at least one mobile station through said low-level stations for supplying a piece of control information representative of said difference between said transmitting time lags to said plurality of low-level stations.

2. The asynchronous transfer mode network as set forth in claim 1, in which each of said first message exchange periods is represented by a first lapse of time between the arrival time of said control message at said corresponding one of said plurality of low-level stations and the arrival time of the respective first response message and each of said plurality of second message exchange periods is represented by a second lapse of time between the time of transmission of said control message and the time of arrival of a respective one of said plurality of second response messages at said high-level station through one of said asynchronous transfer mode channels.

3. The asynchronous transfer mode network as set forth in claim 2, in which a difference in arrival times of said plurality of first response messages respectively at said plurality of low-level stations is corrected in a manner as if said at least one mobile station is equally spaced from said plurality of low-level stations.

4. The asynchronous transfer mode network as set forth in claim 1, in which said difference between said transmission time lags include a first time difference arising from a signal transmission from said high-level station to said plurality of low-level stations respectively along said asynchronous transfer mode channels and a second difference arising from respective signal transmissions from said plurality of low-level stations to said high-level station.

5. The asynchronous transfer mode network as set forth in claim 4, in which said first time difference is determined on the basis of a difference between said first message exchange periods corresponding to said plurality of low-level stations, and said second time difference is determined on the basis of a difference between said plurality of second message exchange periods and said first time difference.

6. The asynchronous transfer mode network as set forth in claim 5, in which each of said first message exchange periods is represented by a first lapse of time between arrival of said control message at said corresponding one of said plurality of low-level stations and arrival of said respective first response message, and each of said plurality of second message exchange periods is represented by a second lapse of time between the transmission of said control message and arrival of a respective one of said plurality of second response messages at said high-level station through said asynchronous transfer mode channels.

7. The asynchronous transfer mode network as set forth in claim 6, in which said first time difference is determined through a first subtraction between the respective first lapses of time.

8. The asynchronous transfer mode network as set forth in claim 7, in which said second time difference is determined through a second subtraction between the respective second lapses of time and a third subtraction between the difference of said first subtraction and the difference of said second subtraction.

9. The asynchronous transfer mode network as set forth in claim 1, in which said plurality of low-level stations communicate with said at least one mobile station by using a time division multiple access technology.

10. A synchronizing system comprising:

a high-level station including

a message transmission unit,

a measuring unit for measuring a response time period, and

a built-in clock;

a plurality of wireless base stations each including

a respective message relaying unit,

a respective measuring unit for measuring a respective response time period, and

a respective built-in clock;

a mobile station including a message response unit; and

an asynchronous transfer mode network for communication between at least said high-level station and said plurality of wireless base stations,

wherein when said mobile station is communicable with said plurality of wireless base stations, transmission time periods are measured between said high-level station and said plurality of wireless base stations, and a difference between the measured transmission time periods is accounted for, if necessary.

11. A method of synchronizing base stations in an ATM mobile communication network when a mobile station is in a boundary condition between adjacent base stations, comprising:

sending a first control signal from a high-level station to a plurality of base stations;

relaying the first control signal to the mobile station from one of the plurality of base stations;

after receiving the control signal, transmitting a first response message from the mobile station to the plurality of base stations;

at each base station, sending a second response message to the high-level station after receiving the response message;

at the high-level station, calculating a time lag of each base station based on the second response messages received from each of the base stations and the corresponding arrival times thereof; and

transmitting, from the high-level station, a second control message to the plurality of base stations to synchronize the base stations.

12. The method of synchronizing base stations according to claim 11, wherein the first control signal is relayed to the mobile station from a base station among the plurality of base stations which first receives the first control signal from the high-level station.

13. The method of synchronizing base stations according to claim 11, wherein each second response message sent to the high-level station from a corresponding base station contains information of the arrival time of the first response

message from the mobile station at the respective base station, and the lapse of time between the time of arrival of the first control message from the high-level station at the respective base station and the time of arrival of the first response message from the mobile station.

14. The method of synchronizing base stations according to claim **11**, wherein the time lag of each base station is calculated by determining a first difference between the arrival times of the second response messages in the high-level station, and a second difference between the lapses of time contained in the received second response messages, and then subtracting the second difference from the first difference.

15. The synchronizing system according to claim **10**, wherein the difference in transmission time periods is resolved in the plurality of base stations.

16. The synchronizing system according to claim **15**, wherein the difference in transmission time periods is resolved by resetting at least one of the respective built-in clocks in the plurality of base stations.

17. The synchronizing system according to claim **10**, wherein the base stations become synchronized with each other upon accounting for the transmission time period difference.

18. The synchronizing system according to claim **10**, wherein the measured transmission time period between said high-level station and each of said plurality of wireless base stations encompasses a transmission time period between said mobile station and the respective wireless base station.

19. The synchronizing system according to claim **10**, wherein the measured transmission time period between said high-level station and each of said plurality of wireless base stations includes a transmission time period between said mobile station and the respective wireless base station as well as a round trip transmission time between said respective wireless base station and said high-level station.

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(12) **United States Patent**
Akhteruzzaman et al.

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(45) **Date of Patent: Jun. 24, 2003**

(54) **HANDOFF OF PHONE CALLS FROM WIRELESS TO WIRELINE NETWORK**

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(73) Assignee: **Lucent Technologies Inc.**, Murray Hill, NJ (US)

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(58) **Field of Search** 455/445, 461, 455/436, 466, 456, 417

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,673,331 A	*	6/1972	Hair et al.	704/203
5,479,482 A		12/1995	Grimes	379/59
5,815,538 A		9/1998	Grell et al.	375/356
5,982,324 A		11/1999	Watters et al.	342/357
6,038,451 A	*	3/2000	Syed et al.	455/445
6,151,500 A	*	11/2000	Cardina et al.	455/435
6,181,780 B1	*	1/2001	Finnigan	379/67.1
6,233,448 B1	*	5/2001	Alperovich et al.	455/414
6,285,984 B1	*	9/2001	Speicher	705/14
6,301,474 B1	*	10/2001	Hartmaier et al.	455/417
6,393,288 B1	*	5/2002	Sollee et al.	455/433

* cited by examiner

Primary Examiner—Thanh Cong Le
Assistant Examiner—Lana Le
(74) *Attorney, Agent, or Firm*—Emrich & Dithmar

(57) **ABSTRACT**

Telephone calls are handed off from a wireless network to a wireline network under the control of a subscriber. When at a given location, the subscriber enters the directory number of the wireline terminal (typically the closest) to which a future wireless call is to be transferred. The entered directory number is then stored in memory in the subscriber's wireless terminal with the current location of the subscriber as determined by a satellite-based global positioning system (GPS) for future use. If the subscriber wants to transfer a call to a wireline terminal, the subscriber selects a transfer handoff key on the subscriber's wireless terminal. After the subscriber's location is determined using the GPS, it is then determined if a directory number (DN) of a designated wireline terminal has previously been entered and stored in memory for the subscriber's present location. If so, the call is transferred to the designated wireline terminal using the local cellular network and the wireless call is terminated. If the DN of a wireline terminal associated with the subscriber's present location has not previously been entered, the wireless call is allowed to continue. Automatic call forwarding to a designated wireline terminal is also provided for in the event of a weak received signal link using a table of previously entered wireline terminal DN's. In both manual and automatic transfer of a wireless call, the subscriber must pick up the ringing wireline terminal to complete call transfer.

13 Claims, 5 Drawing Sheets

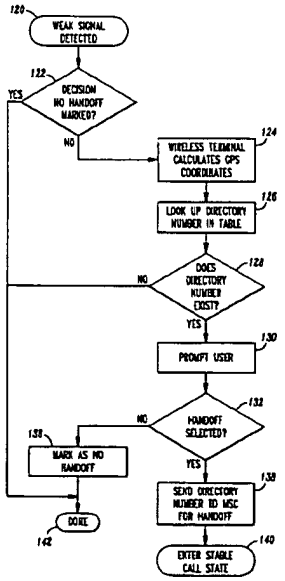


FIG. 1

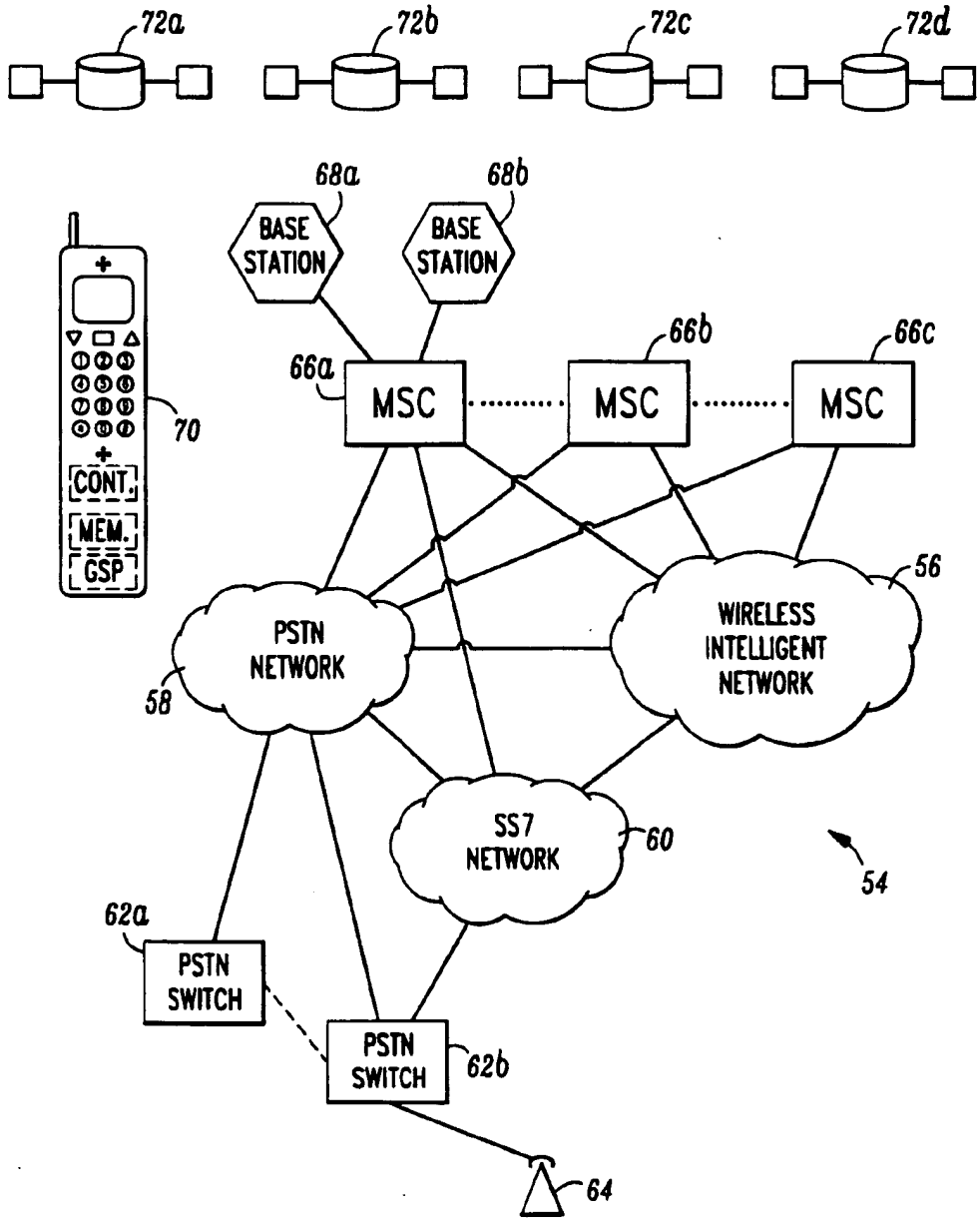

72a
72b
72c
72d
68a
68b
BASE STATION
BASE STATION
66a
66b
66c
MSC
MSC
MSC
70
CONT.
MEM.
GSP
56
PSTN NETWORK
58
WIRELESS INTELLIGENT NETWORK
SS7 NETWORK
60
54
62a
PSTN SWITCH
PSTN SWITCH
62b
64

FIG. 2

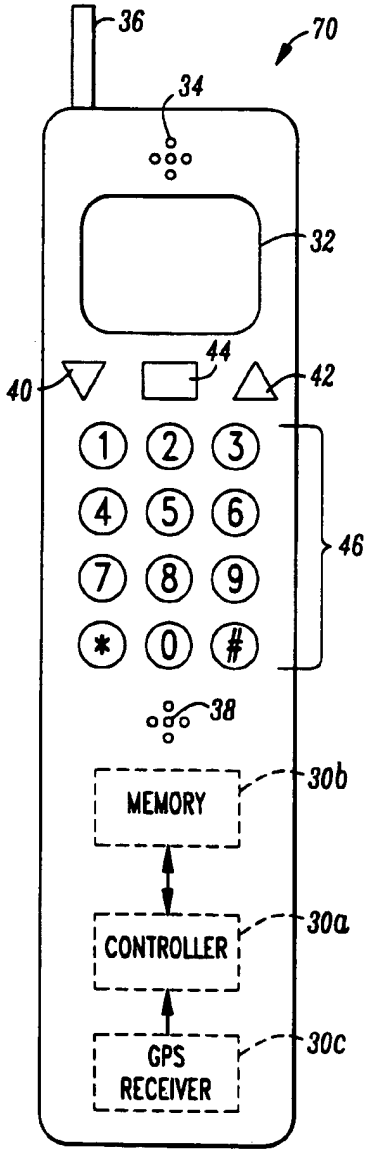

36
70
34
32
44
40
42
1 2 3
4 5 6
7 8 9
* 0 #
46
38
MEMORY
30b
CONTROLLER
30a
GPS RECEIVER
30c

FIG. 3

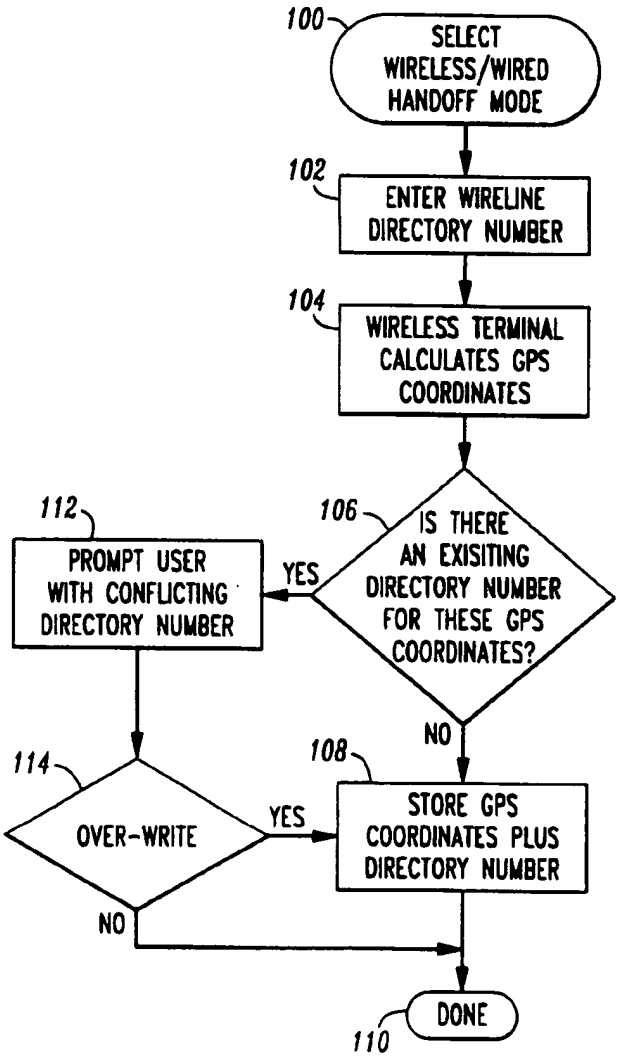

100
SELECT WIRELESS/WIRED HANDOFF MODE
102
ENTER WIRELINE DIRECTORY NUMBER
104
WIRELESS TERMINAL CALCULATES GPS COORDINATES
106
IS THERE AN EXISITING DIRECTORY NUMBER FOR THESE GPS COORDINATES?
YES
112
PROMPT USER WITH CONFLICTING DIRECTORY NUMBER
NO
108
STORE GPS COORDINATES PLUS DIRECTORY NUMBER
114
OVER-WRITE
YES
NO
DONE
110

FIG. 4

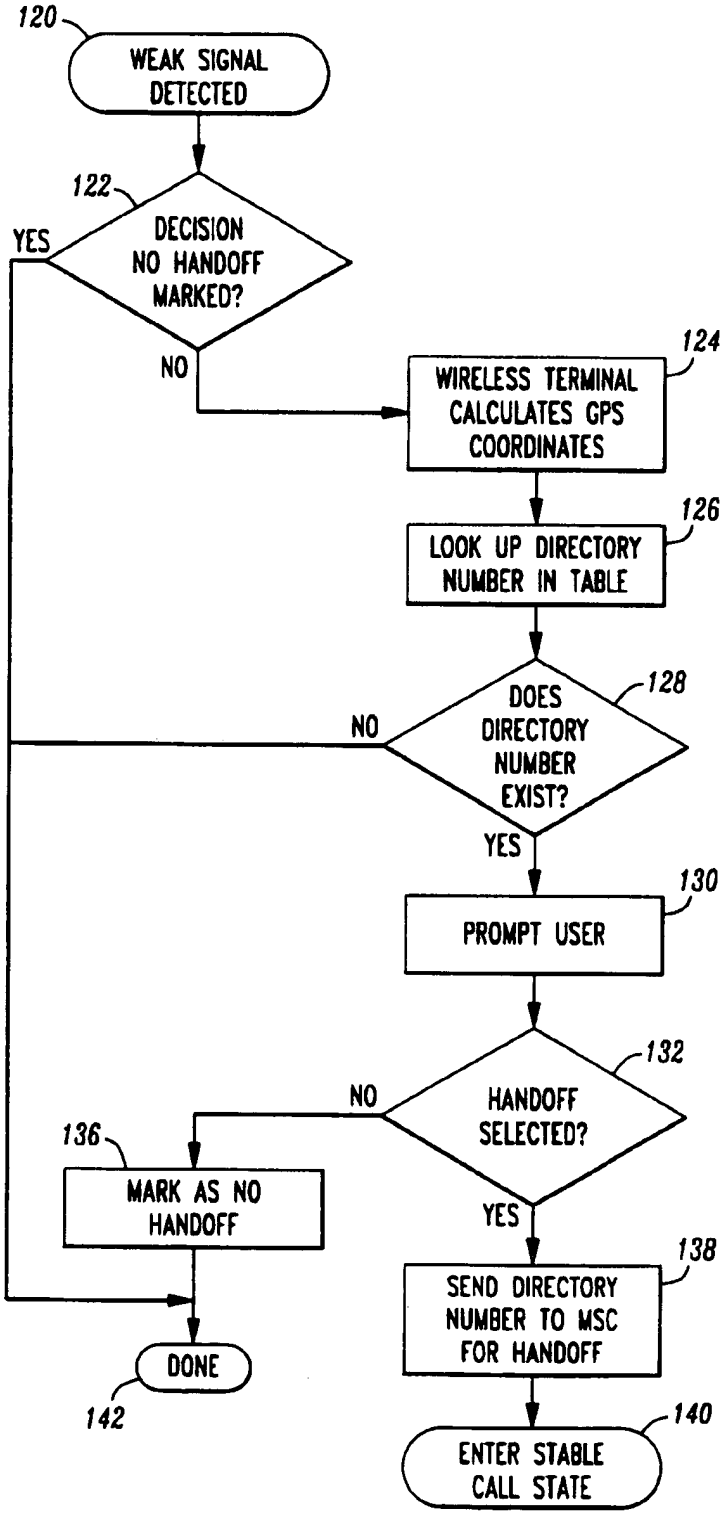

120
WEAK SIGNAL DETECTED
122
DECISION NO HANDOFF MARKED?
YES
NO
124
WIRELESS TERMINAL CALCULATES GPS COORDINATES
126
LOOK UP DIRECTORY NUMBER IN TABLE
128
DOES DIRECTORY NUMBER EXIST?
NO
YES
130
PROMPT USER
132
HANDOFF SELECTED?
NO
YES
136
MARK AS NO HANDOFF
138
SEND DIRECTORY NUMBER TO MSC FOR HANDOFF
140
ENTER STABLE CALL STATE
DONE
142

FIG. 6

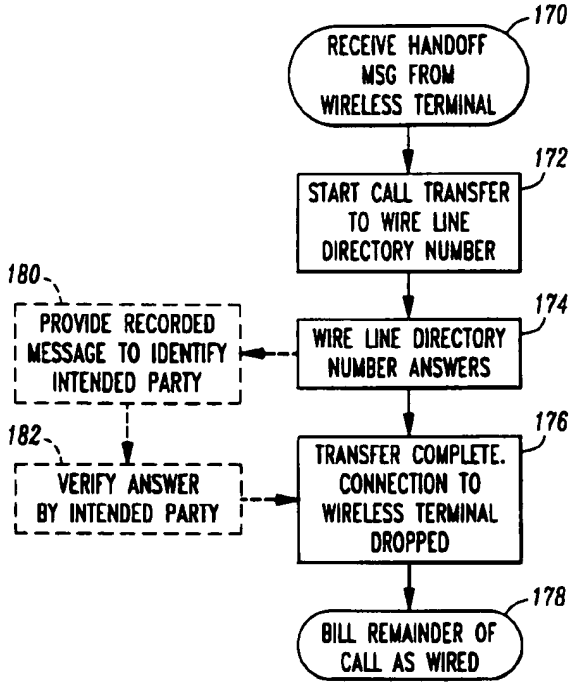

170
RECEIVE HANDOFF MSG FROM WIRELESS TERMINAL
172
START CALL TRANSFER TO WIRE LINE DIRECTORY NUMBER
180
PROVIDE RECORDED MESSAGE TO IDENTIFY INTENDED PARTY
174
WIRE LINE DIRECTORY NUMBER ANSWERS
182
VERIFY ANSWER BY INTENDED PARTY
176
TRANSFER COMPLETE. CONNECTION TO WIRELESS TERMINAL DROPPED
178
BILL REMAINDER OF CALL AS WIRED

FIG. 5

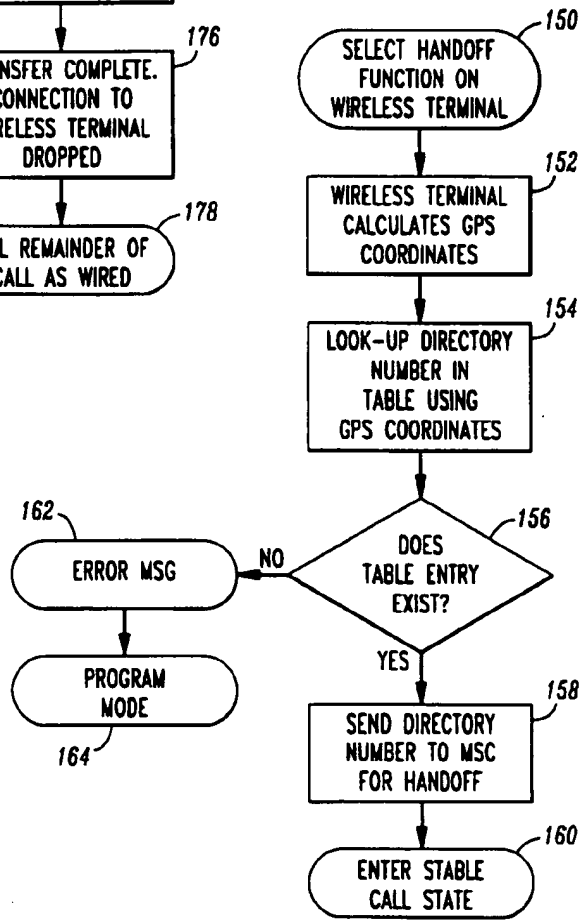

150
SELECT HANDOFF FUNCTION ON WIRELESS TERMINAL
152
WIRELESS TERMINAL CALCULATES GPS COORDINATES
154
LOOK-UP DIRECTORY NUMBER IN TABLE USING GPS COORDINATES
156
DOES TABLE ENTRY EXIST?
NO
162
ERROR MSG
PROGRAM MODE
164
YES
158
SEND DIRECTORY NUMBER TO MSC FOR HANDOFF
160
ENTER STABLE CALL STATE

FIG. 7

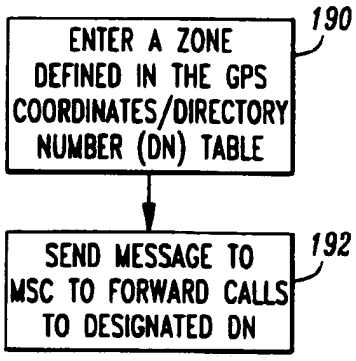


FIG. 8

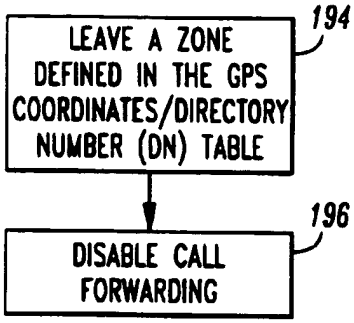
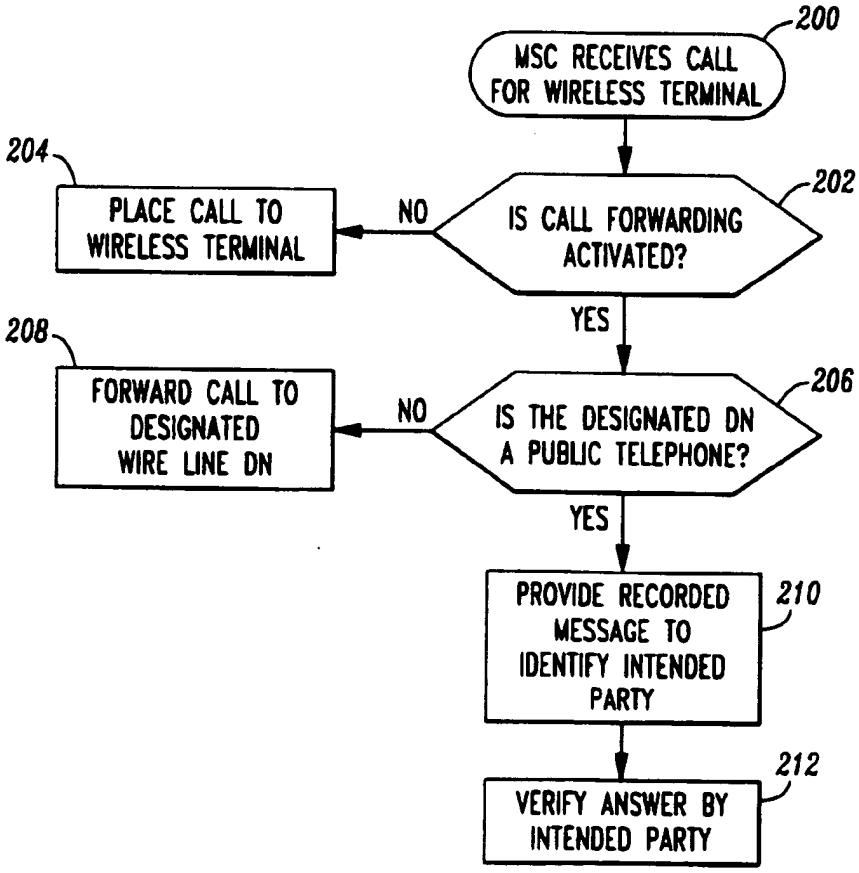


FIG. 9



HANDOFF OF PHONE CALLS FROM WIRELESS TO WIRELINE NETWORK

TECHNICAL FIELD OF THE INVENTION

This invention relates generally to wireline and wireless telephone networks and is particularly directed to the handoff of calls from a wireless network to a wireline network either manually under the control of a subscriber or automatically such as in the event of a weak received signal.

BACKGROUND OF THE INVENTION

Telephone-communication today is accomplished either by a wireline or a wireless telephone network. The wireline telephone network includes a first voice terminal (first subscriber set), a wireline to a switching office, large capacity physical trunks between switching offices, and a wire line to another voice terminal, (second subscriber set). The switching offices as well as the connection between the switching offices is known as a Public Switched Telephone Network (PSTN). The major components of a wireless telephone network, or cellular system, include a Mobile Switch Center (MSC), a Base Station (BS), also known as a Cell Site (CS), and a Mobile Station (MS), also known as a Mobile Unit (MU). The MSC interconnects the cellular system with the PSTN.

Currently, if a subscriber or user (which terms are used interchangeably hereafter) originates a telephone call on a cellular network and desires to continue the call on a wireline network the call must be disconnected on the cellular network and re-established on the wireline network. This is typically accomplished by terminating operation of the mobile unit, followed by initiating a new call via a wireline terminal to the directory number to which the terminated call was placed. Terminating the call on the cellular network and re-establishing the call on the wireline network may be desirable for various reasons. For example, the caller may wish to terminate the call on the cellular network and re-establish it on the wireline network to obtain the benefit of better voice quality and less expensive service on the wireline network. While it may be desirable under certain circumstances to transfer the call, the process of transferring the call is cumbersome, inefficient and time consuming.

In addition, today wireless users have available a call forwarding feature which may be used to temporarily direct inbound calls to another number which may be a wireline terminal number. Wireless calls may be forwarded to a wireline terminal to avoid wireless airtime charges or the effect of a low signal strength area when the mobile subscriber is near a designated wireline terminal. The process of activating/deactivating call forwarding is manual, cumbersome, and prone to error. Each time the wireless subscriber nears a wireline terminal to which it is desired to direct new, inbound calls, the subscriber must program the wireline terminal's directory number as the forwarded number. Additionally, when the subscriber leaves the vicinity of the wireline terminal, the subscriber must deactivate call forwarding or inbound calls will continue to be sent to the wireline terminal that the subscriber is no longer in close proximity to.

The present invention addresses the aforementioned limitations of the prior art by providing for the handoff of a telephone call from a first wireless network to a second wireline network either manually or automatically. The present invention also provides for the automatic activation/deactivation of call forwarding to selected, preprogrammed wireline terminal numbers.

SUMMARY OF THE INVENTION

The present invention contemplates the handing off of telephone calls from a wireless network to a traditional wireline network either automatically or under the control of the subscriber. In order to later transfer a telephone call from the wireless to the wireline network, the subscriber, when in the vicinity of a designated wireline terminal to which it is desired to transfer a call, selects a transfer handoff key on the mobile terminal and enters the directory number (DN) of the designated wireline terminal. At this time, the wireless terminal determines the present coordinates of the subscriber by means of a satellite-based global positioning system (GPS) and stores the wireline terminal DN and present coordinates in a table in its memory for later use. The telephone number of the designated wireline terminal is thus matched with a given set of coordinates for possible future use in transferring a wireless telephone call to the wireline network.

When the subscriber desires to transfer a wireless call to the wireline network, the subscriber selects the handoff function key on the mobile terminal. The mobile terminal then determines its present coordinates using GPS information, compares its present coordinates with the coordinates of various wireline terminals whose directory numbers are stored in memory, determines the wireline terminal closest to its present coordinates within a predetermined range from its present coordinates, and transfers the call to that wireline terminal. Transfer of the call from the wireless network to the wireline network is accomplished by the wireless terminal providing the wireline directory number of the designated wireline terminal to the Mobile Switching Center (MSC) of the wireless network. The MSC then bridges the wireless call to the wireline terminal and provides a signal to the designated wireline terminal. The subscriber then picks up the receiver at the designated wireline terminal resulting in an "answer" signal being transmitted from the designated wireline terminal to the MSC. The MSC then drops the connection to the wireless terminal while maintaining the connection between the designated wireline terminal and the other party.

Another embodiment of the invention allows a subscriber to have wireless calls automatically forwarded to a designated wireline terminal (or perhaps plural wireline terminals) if the signal strength is weak whenever the wireless terminal is within a predetermined distance from the wireline terminal (or terminals) as determined by the location of both terminals using GPS coordinate information. This allows for the automatic forwarding of a wireless telephone call to the nearest wireline terminal to provide the best possible telephone call reception.

BRIEF DESCRIPTION OF THE DRAWINGS

The appended claims set forth those novel features which characterize the invention. However, the invention itself, as well as further objects and advantages thereof, will best be understood by reference to the following detailed description of a preferred embodiment taken in conjunction with the accompanying drawings, where like reference characters identify like elements throughout the various figures, in which:

FIG. 1 is a simplified schematic diagram of a combined wireline and wireless communications network employing position locating satellites for handing off telephone calls

from the wireless to the wireline network in accordance with the present invention;

FIG. **2** is a simplified schematic diagram shown partially in phantom of a wireless terminal and control panel therefor for use in handing off telephone calls from a wireless to a wireline network in accordance with the present invention;

FIG. **3** is a simplified flow chart illustrating the series of steps involved in storing a designated wireline directory number with an associated set of coordinates in the memory of a wireless terminal for possible later use in transferring a wireless call to the designated wireline directory number based upon the location of the wireless terminal or in activating automatic call forwarding to a designated wireline terminal;

FIG. **4** is a simplified flow chart illustrating the steps involved in the automatic handoff of a wireless telephone call from a wireless terminal to a designated wireline terminal in the vicinity of the wireless terminal in accordance with another aspect of the present invention;

FIG. **5** is a simplified flow chart illustrating the series of steps involved in manually transferring a telephone call from a wireless terminal to a designated wireline terminal in accordance with the another aspect of the present invention;

FIG. **6** is a simplified flow chart illustrating the steps involved in handing off a telephone call from a wireless terminal to a wireline terminal via a Mobile Switching Center in accordance with the principles of the present invention; and

FIG. **7** is a simplified flow chart illustrating the steps carried out in activating an automatic call forwarding mode from a wireless terminal to a wireline terminal in accordance with another aspect of the present invention;

FIG. **8** is a simplified flow chart illustrating the steps involved in disabling an automatic call forwarding mode of operation from a wireless terminal to a wireline terminal in accordance with yet another aspect of the present invention; and

FIG. **9** is a simplified flow chart illustrating the series of steps carried out by a mobile switching center in a cellular telephone network in the automatic call forwarding mode of operation from a wireless to a wireline network in accordance with another aspect of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, there is shown a simplified schematic diagram of a telephone call handoff system **54** employing position locating satellites for handing off telephone calls from a wireless network to a wireline network in accordance with the principles of the present invention. The telephone call handoff system **54** includes a cellular telephone network comprised of a signaling system 7 (SS7) network **60**, a wireless intelligent network **56**, plural Mobile Switching Centers (MSCs) **66***a*, **66***b* and **66***c*, and plural base stations **68***a* and **68***b*. Only the first MSC **66***a* as shown with base stations **68***a* and **68***b* for simplicity, it being understood that the second and third MSCs **66***b* and **66***c* similarly support plural base stations in the cellular network. MSCs are involved with switching calls between different base stations, or cell sites, in realtime as a subscriber moves from one area of coverage of one base station to that of another. This process is known as call "handoff" of a subscriber mobile terminal **70** between adjacent base stations. Each MSC serves as a central coordinator and controller for the cellular services within its area and functions as an interface between each base station and a Public Switched Telephone Network (PSTN) **58** to which the MSC is connected. All of the information exchanged between MSCs **66***a*, **66***b* and **66***c* and the PSTN network **58** is done by standard telephone signaling techniques. Each MSC administers radio channels allocated to the cellular system and to individual base stations, coordinates paging and handoff functionality, and maintains the integrity of the cellular system.

The PSTN network **58** typically includes plural PSTN switches **62***a* and **62***b* as well as a large number of wireline terminals, where one of the wireline terminals is shown as element **64** in the figure. The PSTN network **58** is connected to the MSCs **66***a*, **66***b* and **66***c*, as well as to the wireless intelligent network **56** and the SS7 network **60**. All of the elements discussed thus far are standard components of a combined wireline and wireless communications network. It is in the unique operation of the subscriber mobile terminal **70** and MSCs **66***a*, **66***b* and **66***c* that the present invention resides.

The telephone call handoff system **54** further includes plural satellites orbiting the earth such as shown for the case of satellites **72***a*, **72***b*, **72***c* and **72***d*. The satellites are of the global positioning type and are preferably part of the Global Positioning System (GPS) operated by the U.S. Department of Defense. This well known navigation and location system employs triangulation using synchronized signals received from four or more of a set of GPS satellites orbiting the earth. The present invention employs the position locating feature of the GPS for identifying the current coordinates of a wireless terminal **70** having a GPS receiver. This allows the wireless terminal **70** to determine its present geographic location in terms of latitude and longitude coordinates. Determining the present geographic location of the wireless terminal **70** may employ any of the more common approaches now available to determining present latitude and longitude coordinates as briefly discussed in the following paragraph.

One approach that could be used in providing the wireless terminal **70** with its present latitude and longitude coordinates is disclosed in U.S. Pat. No. 5,479,482. In this approach, a GPS receiver in a cellular terminal receives geo-coordinate information from plural GPS satellites. The cellular terminal converts these geo-coordinates to present location information, which location information is then transmitted to a public safety answering point via a cellular switching system such as to provide public emergency call location information. Another approach which could be used in the present invention to provide present location information for wireless terminal **70** is disclosed in U.S. Pat. No. 5,815,538. In this approach, the location of a subscriber device in a wireless cellular communications system is established by transmitting digital data signals to a cellular digital data receiver in the subscriber device from at least three different cellular cell site transmitters at known locations. Each data signal includes a time-synchronized synchronization signal which is preferably synchronized through the time signals of the global positioning system. The time of arrival of each of the time-synchronized synchronization signals is determined with respect to an internal clock of the receiver. The present location of the subscriber device is established from the known locations of the several cell sites in combination with the times of arrival of the synchronization signals relative to the receiver's internal clock. Still another approach which could be used in the present invention for providing present location information to wireless terminal **70** is disclosed in U.S. Pat. No. 5,982,324. In this approach, a cellular network is utilized to collect

differential GPS error correction data which is forwarded to a mobile terminal via the cellular network. The mobile terminal receives this data, along with GPS pseudoranges using a GPS receiver and calculates its position using this information. In another embodiment, when the requisite number of GPS satellites are not in view of the mobile terminal, a GPS pseudosatellite signal transmitted from a base station in the cellular network is received by the mobile terminal and processed as a substitute for the missing GPS satellite signal. A third embodiment is used when the requisite number of GPS satellites are not in clear view of the GPS receiver, with the system then switching from relying on the GPS portion of the system to utilizing the cellular network infrastructure to determine location. This is done by using either time of arrival (TOA) or time difference of arrival (TDOA) methods for determining location in the cellular network portion of the system. When the mobile terminal is moved to a location where the requisite number of satellites are again in clear view of GPS receiver, the system switches back to using the GPS portion of the system to determine location. Any of the aforementioned approaches for accurately determining the position of the wireless terminal **70** could be used in implementing the present invention.

Referring to FIG. **2**, there is shown a combined plan view and simplified schematic diagram of the wireless terminal **70** used in the present invention. As shown in the figure, the wireless terminal **70** includes a video display **32**, such as, for example, in the form of a liquid crystal diode (LCD) screen for presenting information to the subscriber. Wireless terminal **70** further includes a speaker **34**, a microphone **38**, and an antenna **36**. Wireless terminal **70** also includes a set off alphanumeric keys **46**, as well as menu down and menu up selectors **40**, **42** and a soft selector key **44**. The menu down and menu up selectors, **40**, **41** permit the soft selector key **44** to be used in various functional modes. One mode in which the soft selector key **44** is used in the present invention is as a call transfer handoff key for manually transferring a call from a wireless to a wireline network as described below. Another mode in which the soft selector key **44** is used in the present invention is to store in memory the present coordinates of the mobile terminal **70** as well as the directory number to (DN) of a wireline terminal in the vicinity of the wireless terminal to which a telephone call is to be transferred. The handheld mobile terminal **70** also includes a controller **30***a*, a memory **30***b* and a GPS receiver **30***c*. Controller **30***a* controls the operation of the mobile terminal **70** in accordance with an operating program stored therein. Memory **30***b* stores such information as geographic coordinates and directory numbers of wireline terminals located in the vicinity of stored geographic coordinates for the transfer of telephone calls as described below. The GPS receiver **30***c* permits the wireless terminal **70** to accurately determine its present location using GPS coordinate information. The handheld mobile terminal **70** is used in the following manner to hand off a telephone call from a wireless to a wireline network.

Referring to FIG. **3**, there is shown a simplified flow chart illustrating the series of steps involved in storing a designated wireline directory number (DN) with an associated set of geographic coordinates in the memory **30***b* of the wireless terminal **70** for possible later use in transferring a wireless call to the designated wireline directory number based upon the present location of the wireless terminal in accordance with one aspect of the present invention. A subscriber must initially determine to which wireline terminal it is desired to hand off a wireless telephone call when at a given location. This procedure is initiated at step **100** by the subscriber selecting the soft selector key **44** on the wireless terminal **70** for initiating the handoff mode. In this mode, the soft selector key **44** is used to store information in memory **30***b*. The subscriber then at step **102** enters the DN of the wireline terminal to which it is desired to transfer a wireless telephone call at the present location of the wireless terminal **70**. The wireless terminal **70** then automatically at step **104** determines its present location in latitude and longitude coordinates based upon information received by the wireless terminal's GPS receiver **30***c*. The wireless terminal's controller **30***a* at step **106** then determines if there is an existing directory number stored in the terminal's memory **30***b* for the coordinates calculated at step **104** or which overlaps within a predetermined range a previously stored directory number. If at step **106** it is determined that there is not an existing directory number in the wireless terminal's memory **30***b*, the program proceeds to step **108** and stores the GPS coordinates calculated at step **104** together with the wireline directory number entered at step **102** in the wireless terminal's memory **30***b* in an associated manner. The program then proceeds to step **110** and is completed. If at step **106** it is determined that there is an existing directory number for the calculated GPS coordinates stored in the wireless terminal's memory **30***b*, the program proceeds to step **112** and provides a prompt to the subscriber such as on the terminal's video display **32** that there are conflicting directory numbers. The program then at step **114** allows the subscriber to overwrite the existing directory number with the wireline directory number entered in step **102**. The program then proceeds to step **108** for storing the GPS coordinates calculated at step **104** with the wireline directory number entered at step **102** in the wireless terminal's memory **30***b*. If the subscriber elects not to overwrite the existing directory number in the wireless terminal's memory **30***b* at step **114**, the program proceeds to step **110** and is completed.

Referring to FIG. **4**, there is shown a simplified flow chart illustrating the steps involved in the automatic handoff of a wireless telephone call to a designated wireline terminal in accordance with another aspect of the present invention. FIG. **4** also shows the series of steps involved in activating automatic call forwarding to a designated wireline terminal in accordance with another aspect of the present invention. The automatic transfer of a wireless call to a wireline terminal is initiated at step **120** with the detection by the wireless terminal **70** of a weak received signal. Conventional means such as a software routine or a signal strength comparator circuit or threshold level detection circuit may be used in the wireless terminal **70** to determine if the received signal strength is less than a predetermined level. The program then proceeds to step **122** and determines if the decision has been made in the program not to handoff a weak received signal to a designated wireline terminal. If the program does not provide for the automatic handoff of a wireless telephone call in the event of a weak received signal, the program proceeds to step **142** and is complete. If at step **122** it is determined that a wireless telephone call with a weak received signal is to be automatically handed off to a wireline terminal, the program proceeds to step **124** with the wireless terminal calculating its current GPS coordinates using information from its GPS receiver. The program then proceeds to step **126** to look up a directory number stored in the wireless terminal's memory **30***b* associated with the GPS coordinates calculated at step **124**. If the program at step **128** determines that there is no directory number stored in the wireless terminal's memory **30***b* associated with the GPS coordinates calculated at step **124**, the program proceeds to

step **142** and is complete. If at step **128** it is determined that a directory number associated with the GPS coordinates calculated at step **124** is stored in the wireless terminal's memory **30***b*, the program proceeds to step **130** and prompts the subscriber so that the call can be handed off to a designated wireline terminal. If at step **132** a subscriber elects not to hand off the wireless telephone call to a designated wireline terminal, the program proceeds to step **136** and marks the call as do not execute a call handoff and then proceeds to step **142** and is completed. If at step **132** the subscriber elects to handoff the wireless telephone call having an associated weak signal strength by providing the appropriate input command on the wireless terminal **70**, the program proceeds to step **138** and provides the directory number of the designated wireline terminal stored in the wireless terminal's memory **30***b* to an MSC in the cellular network for handing off the telephone call. The program then proceeds to step **140** and enters the stable call state for transferring the wireless call to the designated wireline terminal.

Referring to FIG. **5**, there is shown a simplified flow chart illustrating the steps involved in manually transferring a wireless call under the control of the subscriber to a designated wireline terminal. The program is initiated at step **150** with the selection by the subscriber of the soft selector key **44** in the call transfer mode on the wireless terminal **70**. The program stored in the wireless terminal's controller **30***a* then calculates the current GPS coordinates of the wireless terminal at step **152** using GPS positioning information. The program then proceeds to step **154** and determines if there is an associated directory number for a wireline terminal for the GPS coordinates calculated at step **152** stored in the wireless terminal's memory **30***b*. The program then determines at step **156** if a directory number associated with the calculated GPS coordinates is stored in a table in the wireless terminal's memory **30***b*. If at step **156** it is determined that there is no directory number stored in the wireless terminal's memory **30***b* associated with the GPS coordinates calculated at step **152**, the wireless terminal displays an error message on its video display **32** at step **162** permitting the subscriber to select the program mode at step **164** which is described above and shown in FIG. **3**. If at step **156** it is determined that a directory number associated with the GPS coordinates calculated at step **152** is stored in the wireless terminal's memory **30***b*, the program proceeds to step **158** and transmits the directory number from the wireless terminal to an MSC of the wireless network for handing the wireless call off to the designated wireline terminal. The program then proceeds to step **160** and enters the stable call state for transferring the wireless call to the designated wireline terminal.

Referring to FIG. **6**, there is shown a simplified flow chart illustrating the steps carried out by an MSC of the cellular network in transferring a call from a wireless terminal to a designated wireline terminal in accordance with another aspect of the present invention. The program stored in the MSC is initiated at step **170** with receipt by the MSC of a handoff message from the wireless terminal from which the telephone call is to be transferred. The MSC program then at step **172** initiates a call transfer to the directory number of the designated wireline terminal from the wireless terminal. The call to the designated wireline terminal which has its directory number stored in the wireless terminal's memory **30***b* is then answered at step **174** by the subscriber. The MSC program then completes transfer of the telephone call at step **176** to the designated wireline terminal and drops the connection to the wireless terminal from which the telephone call has been transferred. The program stored in the MSC then bills the remainder of the call at the wireline telephone call rate at step **170** which is generally less than the rate of a wireless telephone call.

The wireline terminal to which a telephone call is transferred may be a public telephone. In this event, after the call to the designated wireline directory number is answered as shown in step **174** in FIG. **6**, the program in the MSC provides a prerecorded message to identify the intended party of the transferred call at step **180** as shown in dotted line form in FIG. **6**. Examples of such prerecorded messages may be "Call from John Smith, please have John Smith come to the phone" and to the party at the other end of the line "Please hold while we contact your party". Conventional means such as voice recognition may then be used at step **182** (also shown in phantom) to verify that the call has been answered by the intended party. If the intended party does not answer the transferred telephone call within a predetermined time, the transferred telephone call is dropped and the caller may be routed to the intended party's voice mail. After verifying that the intended party has answered the transferred call at the designated wireline terminal at step **182**, the program proceeds to step **176** for completing transfer of the call to the wireline terminal and dropping the connection to the wireless terminal.

Referring to FIG. **7**, there is shown in simplified flow chart form the steps carried out in activating an automatic call forwarding mode from a wireless terminal to a wireline terminal having a designated DN in accordance with another aspect of the present invention. At step **190**, a subscriber having, the mobile terminal enters a zone defined in terms of geographic coordinates previously stored in a table. Each set of geographic coordinates is stored in the table with an associated DN of a wireline terminal located at or near the stored geographic coordinates. Thus, each set of geographic coordinates is stored in the table with the DN of an associated wireline terminal located at or near the stored coordinates. At step **192**, a message is sent from the mobile terminal to the mobile switching center (MSC) of the cellular network by means of a data link for actuating an automatic call forwarding mode of operation to a designated DN. Thus, a call placed to a mobile terminal of a subscriber located near or in the vicinity of a designated wireline terminal in a given zone will result in automatic forwarding of the call to the designated wireline terminal.

Referring to FIG. **8**, there is shown a simplified flow chart of the steps involved in disabling the automatic call forwarding mode of operation just described in terms of FIG. **7** in accordance with another aspect of the present invention. At step **194**, the subscriber leaves a zone defined in terms of geographic coordinates and having an associated DN of a designated wireline terminal stored in the table. At step **196**, the automatic call forwarding mode is disabled and calls to the mobile terminal will no longer be automatically forwarded to the designated wireline DN because the mobile subscriber has departed from the vicinity, or zone, of the designated wireline DN. A disabling signal is provided from the mobile terminal to the MSC via the aforementioned data link in a conventional manner. The table in which the geographic coordinates and directory numbers are stored is located in the mobile terminal which permits the mobile terminal, using its GPS receiver, to continuously compare its present location with the stored coordinates of the designated wireline terminals for automatic call forwarding. The size of a given zone associated with the location of a designated wireline terminal may be fixed as desired using conventional programming.

Referring to FIG. **9**, there is shown a simplified flow chart of the series of steps involved in the automatic call forwarding of a call placed to a mobile terminal which is forwarded to a designated wireline terminal. At step **200**, the MSC receives a call for a wireless terminal. At step **202**, a program stored in the MSC determines if automatic call forwarding is activated. If automatic call forwarding is not activated, the program proceeds to step **204** and places the call to the wireless terminal having the selected DN. If at step **202** it is determined that automatic call forwarding is activated, the program proceeds to step **206** and determines if the designated DN is a public telephone. If at step **206** it is determined that the designated DN is not a public telephone, the program proceeds to step **208** and forwards the call to the designated, non-public telephone wireline DN. If at step **206** it is determined that the designated DN is a public telephone, the program proceeds to step **210** and provides a recorded message to the designated public telephone for the purpose of identifying the intended party of the call as described above with respect to FIG. **6**. The program then proceeds to step **212** for verifying that the call has been answered by the intended party at the designated public telephone DN also is previously described with respect to FIG. **6**.

While particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the relevant arts that changes and modifications may be made without departing from the invention in its broader aspects. Therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only and not as a limitation. The actual scope of the invention is intended to be defined in the following claims when viewed in their proper perspective based on the prior art.

We claim:

1. A method for handing off a telephone call from a first terminal in a wireless network to a second terminal in a wireline network, wherein said second terminal has an associated directory number, said method comprising the steps of:

storing in a memory in the first terminal the directory number of the second terminal when the first terminal is in the vicinity of the second terminal;

determining the geographic coordinates of the first terminal when the first terminal is in the vicinity of the second terminal;

storing the geographic coordinates with the directory number in said memory in an associated manner;

placing a telephone call on the wireless network using the first terminal;

selecting a telephone call handoff selector key on the first terminal for transferring the telephone call to the wireline network;

determining the current geographic coordinates of the first terminal and comparing said current geographic coordinates with the geographic coordinates stored in said memory;

generating a signal to initiate the transfer of the telephone call to the second terminal if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory; or

comparing a signal strength of a telephone call from the first terminal in the wireless network with a reference signal level and, if the signal strength of the telephone call is less than said reference signal level, determining the current geographic coordinates of the first terminal for automatically transferring the telephone call to the second terminal if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory associated with the second terminal; and

terminating the telephone call on the wireless network.

2. The method of claim **1** further comprising the step of storing in said memory the directory numbers of plural second terminals in the wireline network when the first terminal is in the vicinity of each respective second terminal and further determining and storing the geographic coordinates of the first terminal when in the vicinity of each respective second terminal, wherein each directory number is stored in an associated manner with the geographic coordinates of the first terminal when the first terminal is in the vicinity of a respective second terminal for transferring a telephone call from the wireless network to any of said second terminals in the wireline network.

3. The method of claim **1** further comprising the step of comparing the directory number of the designated wireline terminal with the contents of said memory to determine the presence in said memory of a previously stored directory number associated with the geographic coordinates of said designated wireline terminal and for overriding a directory number previously stored in said memory with the directory number of the designated wireline terminal.

4. The method of claim **1** further comprising the step of changing a billing rate chargeable to a subscriber when the telephone call is switched from the wireless network to the wireline network.

5. The method of claim **1** further comprising the step of providing a voice message to the second terminal for identifying an intended recipient of the telephone call where the second terminal is a public telephone.

6. The method of claim **5** further comprising the step of routing the telephone call to the intended recipient's voice mail if the intended recipient of the telephone call does not respond on the second terminal within a designated time period.

7. A method for handing off a telephone call from a first terminal in a wireless network to a second terminal in a wireline network, wherein said second terminal has an associated directory number, said method comprising the steps of:

storing in a memory in the first terminal the directory number of the second terminal when the first terminal is in the vicinity of the second terminal;

determining the geographic coordinates of the first terminal when the first terminal is in the vicinity of the second terminal;

storing the geographic coordinates with the directory number in said memory in an associated manner;

placing a telephone call on the wireless network using the first terminal;

selecting a telephone call handoff selector key on the first terminal for transferring the telephone call to the wireline network;

determining the current geographic coordinates of the first terminal and comparing said current geographic coordinates with the geographic coordinates stored in said memory;

generating a signal to initiate the transfer of the telephone call to the second terminal if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory;

verifying the identity of a person answering the public telephone as an intended recipient of the telephone call including using voice recognition of the intended recipient of the telephone call; and

terminating the telephone call on the wireless network.

8. A method for handing off a telephone call from a first terminal in a wireless network to one of a plurality of second terminals in a wireline network, wherein each of said second terminals has an associated directory number, said method comprising the steps of:

storing in a memory in the first terminal the directory number of each of said plural second terminals in the wireline network when the first terminal is in the vicinity of each respective second terminal;

determining the geographic coordinates of the first terminal when the first terminal is in the vicinity of each respective second terminal;

storing the geographic coordinates of the first terminal when in the vicinity of each respective second terminal with the directory number of the second terminal that the first terminal is in the vicinity of in said memory in an associated manner;

placing a telephone call on the wireless network using the first terminal;

determining the current geographic coordinates of the first terminal and comparing said current geographic coordinates with the geographic coordinates stored in said memory;

comparing a signal strength of a telephone call from the first terminal in the wireless network with a reference signal level and, if the signal strength of the telephone call is less than said reference signal level, automatically generating a signal to initiate transfer of the telephone call to one of the second terminals if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory associated with said one of the second terminals; and

terminating the telephone call on the wireless network.

9. A method for the automatic forwarding of a telephone call placed to a first terminal in a wireless network to a second terminal in a wireline terminal via a mobile switching center, wherein said second terminal has an associated directory number, said method comprising the steps of:

storing in a memory in the first terminal the directory number of the second terminal when the first terminal is in the vicinity of the second terminal;

determining the geographic coordinates of the first terminal when the first terminal is in the vicinity of the second terminal;

storing the geographic coordinates of the first terminal when in the vicinity of the second terminal with the directory number in said memory in an associated manner;

activating a call forwarding mode of operation in the mobile switching center;

placing a telephone to the first terminal via the wireless network;

determining the current geographic coordinates of the first terminal and comparing said current geographic coordinates with the geographic coordinates stored in said memory;

generating a signal to initiate the transfer of the telephone call to the second terminal if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory; or

comparing a signal strength of a telephone call to the first terminal in the wireless network with a reference signal level and, if the signal strength of the telephone call is less than said reference signal level, determining the current geographic coordinates of the first terminal for automatically transferring the telephone call to the second terminal if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory associated with the second terminal; and

terminating the telephone call on the wireless network.

10. The method of claim 9 further comprising the step of changing a billing rate chargeable to a subscriber when the telephone call is switched from the wireless network to the wireline network.

11. The method of claim 9 further comprising the step of providing a voice message to the second terminal for identifying an intended recipient of the telephone call where the second terminal is a public telephone.

12. The method of claim 11 further comprising the step of routing the telephone call to the intended recipient's voice mail if the intended recipient of the telephone call does not respond on the second terminal within a designated time period.

13. A method for the automatic forwarding of a telephone call placed to a first terminal in a wireless network to a second terminal in a wireline terminal via a mobile switching center, wherein said second terminal has an associated directory number, said method comprising the steps of:

storing in a memory in the first terminal the directory number of the second terminal when the first terminal is in the vicinity of the second terminal;

determining the geographic coordinates of the first terminal when the first terminal is in the vicinity of the second terminal;

storing the geographic coordinates of the first terminal when in the vicinity of the second terminal with the directory number in said memory in an associated manner;

activating a call forwarding mode of operation in the mobile switching center;

placing a telephone to the first terminal via the wireless network;

determining the current geographic coordinates of the first terminal and comparing said current geographic coordinates with the geographic coordinates stored in said memory;

generating a signal to initiate the transfer of the telephone call to the second terminal if the current geographic coordinates of the first terminal match the geographic coordinates stored in said memory;

verifying the identity of a person answering the public telephone as an intended recipient of the telephone call including using voice recognition of the intended recipient of the telephone call; and

terminating the telephone call on the wireless network.

* * * * *

L Number	Hits	Search Text	DB	Time stamp
1	6803	voice adj mail	USPAT; US-PGPUB	2004/07/08 09:35
2	1631	(sync or synchroni$) and (voice adj mail)	USPAT; US-PGPUB	2004/07/08 09:57
3	1310	(mobile or wireless or cellular or radio) and ((sync or synchroni$) and (voice adj mail))	USPAT; US-PGPUB	2004/07/08 09:35
4	193	voice adj mail same (predetermined or specific or specified) near tim$3	USPAT; US-PGPUB	2004/07/08 09:36
5	16	((mobile or wireless or cellular or radio) and ((sync or synchroni$) and (voice adj mail))) and (voice adj mail same (predetermined or specific or specified) near tim$3)	USPAT; US-PGPUB	2004/07/08 09:54
6	353	base adj station near4 (adjust$3 or reset$3) with (time or timing)	USPAT; US-PGPUB	2004/07/08 09:55
7	13970	(device or unit or mobile or station) near2 request$3 same (time or timing)	USPAT; US-PGPUB	2004/07/08 10:01
8	85	(base adj station near4 (adjust$3 or reset$3) with (time or timing)) and ((device or unit or mobile or station) near2 request$3 same (time or timing))	USPAT; US-PGPUB	2004/07/08 09:57
9	65	(sync or synchroni$) and ((base adj station near4 (adjust$3 or reset$3) with (time or timing)) and ((device or unit or mobile or station) near2 request$3 same (time or timing)))	USPAT; US-PGPUB	2004/07/08 09:57
10	12053	(device or unit or mobile) near2 request$3 same (time or timing)	USPAT; US-PGPUB	2004/07/08 10:02
11	28	((sync or synchroni$) and ((base adj station near4 (adjust$3 or reset$3) with (time or timing)) and ((device or unit or mobile or station) near2 request$3 same (time or timing)))) and ((device or unit or mobile) near2 request$3 same (time or timing))	USPAT; US-PGPUB	2004/07/08 10:02
-	22633	incom$3 near (call or page or message)	USPAT; US-PGPUB	2004/07/07 15:29
-	312693	sync or synchroni$	USPAT; US-PGPUB	2004/07/08 09:35
-	6796	(incom$3 near (call or page or message)) and (sync or synchroni$)	USPAT; US-PGPUB	2004/07/07 10:15
-	517880	mobile or wireless or cellular or radio	USPAT; US-PGPUB	2004/07/08 09:35
-	4284	((incom$3 near (call or page or message)) and (sync or synchroni$)) and (mobile or wireless or cellular or radio)	USPAT; US-PGPUB	2004/07/07 10:15
-	2915692	timer or clock or timing or time	USPAT; US-PGPUB	2004/07/07 10:16
-	4246	(((incom$3 near (call or page or message)) and (sync or synchroni$)) and (mobile or wireless or cellular or radio)) and (timer or clock or timing or time)	USPAT; US-PGPUB	2004/07/07 10:17
-	17567	(sync or synchroni$) with (fail$3 or off)	USPAT; US-PGPUB	2004/07/07 10:17
-	517	((((incom$3 near (call or page or message)) and (sync or synchroni$)) and (mobile or wireless or cellular or radio)) and (timer or clock or timing or time)) and ((sync or synchroni$) with (fail$3 or off))	USPAT; US-PGPUB	2004/07/07 15:31
-	168	455$.ccls. and (((((incom$3 near (call or page or message)) and (sync or synchroni$)) and (mobile or wireless or cellular or radio)) and (timer or clock or timing or time)) and ((sync or synchroni$) with (fail$3 or off)))	USPAT; US-PGPUB	2004/07/07 10:18
-	8	("5068916" | "5507039" | "5703873" | "5930366" | "5940381" | "5956650" | "6014406" | "6119015").PN.	USPAT	2004/07/07 10:57
-	599	(adjust$3 or reset$4) near4 tim$4 with base adj station	USPAT; US-PGPUB	2004/07/07 15:38
-	333	455/$.ccls. and ((adjust$3 or reset$4) near4 tim$4 with base adj station)	USPAT; US-PGPUB	2004/07/07 16:00
-	234	(sync or synchroni$) and (455/$.ccls. and ((adjust$3 or reset$4) near4 tim$4 with base adj station))	USPAT; US-PGPUB	2004/07/07 15:59

-	9	((((incom$3 near (call or page or message)) and (sync or synchroni$)) and (mobile or wireless or cellular or radio)) and (timer or clock or timing or time)) and ((sync or synchroni$) with (fail$3 or off)) and ((sync or synchroni$) and (455/$.ccls. and ((adjust$3 or reset$4) near4 tim$4 with base adj station)))	USPAT; US-PGPUB	2004/07/07 15:31
-	143	reset$4 near4 tim$4 with base adj station	USPAT; US-PGPUB	2004/07/08 08:07
-	55	((sync or synchroni$) and (455/$.ccls. and ((adjust$3 or reset$4) near4 tim$4 with base adj station))) and (reset$4 near4 tim$4 with base adj station)	USPAT; US-PGPUB	2004/07/07 15:53
-	1	20020082011.pn.	USPAT; US-PGPUB	2004/07/07 15:54
-	542	base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page)	USPAT; US-PGPUB	2004/07/07 16:02
-	14	((sync or synchroni$) and (455/$.ccls. and ((adjust$3 or reset$4) near4 tim$4 with base adj station))) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page))	USPAT; US-PGPUB	2004/07/07 15:57
-	229	(sync or synchroni$) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page))	USPAT; US-PGPUB	2004/07/07 16:03
-	143	455/$.ccls. and ((sync or synchroni$) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page)))	USPAT; US-PGPUB	2004/07/07 16:00
-	100	incom$ and (455/$.ccls. and ((sync or synchroni$) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page))))	USPAT; US-PGPUB	2004/07/07 16:00
-	82	incom$ adj call and (incom$ and (455/$.ccls. and ((sync or synchroni$) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page)))))	USPAT; US-PGPUB	2004/07/07 16:01
-	51	base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page) same incom$3	USPAT; US-PGPUB	2004/07/07 16:03
-	229	(sync or synchroni$) and ((sync or synchroni$) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page)))	USPAT; US-PGPUB	2004/07/07 16:03
-	11	(sync or synchroni$) and (base adj station with (hold$3 or park$3 or stor$3) near2 (call$3 or message or page) same incom$3)	USPAT; US-PGPUB	2004/07/07 16:03
-	56	request$ near4 tim$3 and ((sync or synchroni$) and (455/$.ccls. and ((adjust$3 or reset$4) near4 tim$4 with base adj station)))	USPAT; US-PGPUB	2004/07/07 16:15
-	1037	reset$4 near4 tim$4 with (base adj station or cell)	USPAT; US-PGPUB	2004/07/08 08:10
-	489	(sync or synchroni$) and (reset$4 near4 tim$4 with (base adj station or cell))	USPAT; US-PGPUB	2004/07/08 08:10
-	151	(mobile or wireless or cellular or radio) and ((sync or synchroni$) and (reset$4 near4 tim$4 with (base adj station or cell)))	USPAT; US-PGPUB	2004/07/08 09:34